HIRDLS

TC-LOC-017

DRAFT

HIGH RESOLUTION DYNAMICS LIMB SOUNDER

Originator: L.G. BURRIESCI
E.A. JOHNSON

Date: 8 March, 1995

Subject/Title: **HIRDLS INSTRUMENT RADIOMETRIC TEST PROGRAM**

Description/Summary/Contents:

1. This document describes the overall radiometric test methodology to be used on the HIRDLS program.

2. It discusses radiometric test techniques and facility requirements

3. It recommends specific locations for testing.

Keywords: Black Body, Calibration, Models, Nearfield, Radiometric, Testing, Verification

Purpose of this Document: (20 char max.)	To describe the overall radiometric test approach for the HIRDLS program.		
Reviewed/Approved by:			
Date (yy-mm-dd):			

EOS

HIRDLS INSTRUMENT RADIOMETRIC TEST PROGRAM

INTRODUCTION

The HIRDLS instrument must collect data which is consistent and correlatable over time. The fundamental radiometric requirement is that the instrument be capable producing data with a basic radiometric accuracy of 0.5% for the most important channels. This must be achieved over the full 5 year operational life of the instrument. Absolute radiometry becomes very challenging as the requirement on absolute error approaches 1%, particulary for an instrument whose characteristics can be expected to gradually change with various contamination and ageing effects in operation.

To achieve the required absolute radiometry over time, sophisticated models must be developed for the HIRDLS instrument. These models must be updated regularly over the operational life of the instrument to account for instrument aging. Updates can be based on various data sources, including certain special test mode and specific deviations from normal operations such as the suggested periodic pitchup of the spacecraft to provide data which may permit correction for changes in scan mirror scattering and emittance properties.

The objective of the HIRDLS test program thus becomes four fold: First, to verify the instrument meets its specifications at the beginning of life (BOL). Second, to verify the instrument models adequately represent the interaction between components as well as accurately predict its performance. Third, to verify the on orbit calibration process is sufficiently accurate and stable to provide the performance updates. And fourth, to achieve the first three within the cost and schedule constraints of the program.

SCOPE

This document describes the overall radiometric test methodology recommended for the HIRDLS program, discuss radiometric test techniques and facility capabilities required to verify the individual requirements, and recommends the physical locations and facilities where each radiometric test are best accomplished.

GENERAL TESTING PHILOSOPHIES

Development of any test program begins with understanding the science experiment objectives. Once these objectives are understood one must then understand how these objectives flow into the requirements, how the requirements flow into the models, how the models flow into the designs, and how the designs flow into hardware. Only then can the test program be developed and the test equipment, and facilities, be identified.

Like many things in life there is rarely only one "right way" to test an instrument. There are however two main approaches that are typically taken when devising a test program.

The first approach is the more traditional of the two. In this approach all instrument requirements are first identified then a test program is developed to satisfy the specification as written on a requirement by requirement basis. This is perhaps the most straightforward approach, and when properly implementd yields high confidence in the performace of the instrument, but is often not optimum in providing insight and useful information per unit cost. This method is often employed because it's easier to implement contractually, and contractors typically get paid when products are delivered. Performance at delivery becomes the most important issue. This approach assumes that the instrument requirements have been

sufficiently defined, understood, and bounded which allows the test program to concentrate solely on the verification of those stated requirements as they are written.

When the requirements are extensive, this method can easily become very expensive; it is difficult to verify all possible combinations of requirements over all operational environments. The test program yields volumes of test data under very specific conditions. If the instrument ever operates outside the specific combinations of conditions under which the test data was obtained, this approach provides little guidance in defining appropriate corrections to the data.

This method of verification is appropriate for production programs or for instruments which are more functional in nature. However, for programs which are pushing the state of the art in their field or whose operating environment may be dynamic, or where performance over time is critical, another verification approach is often more appropriate.

This second approach relies more heavily on mathematical modeling. The principle argument goes, if the inter-workings of the instrument are well understood and can be accurately modeled, the instrument performance can be predicted under all combinations of operating and environmental conditions. With accurate math models one can also predict performance changes as the instrument ages or experiences dynamic environmental conditions or "unanticipated events." In this approach, the test program is geared toward validating the models not to specifically testing against every requirement. One advantage of this approach is that the test program and the facilities requirements can often be reduced because one is no longer required to test each requirement under all combinations of operating and environmental conditions. A second advantage is that the resultant product of the test program is a working model (or models) which can be routinely exercised, not volumes of test data which must be sifted through if an anomaly occurs. There are some disadvantages to this approach, however, which must be acknowledged.

Development of a suitable test program around the second approach (validating the math models) requires experienced people and considerable discipline. The test development process not only includes test design (how do I test this requirement?), but also requires a more conceptual understanding of the instrument and its operational environments to decide which parameters of a given model are critical and which are not (verifying which parameters will yield the greatest insight into the validity of the model?). Because of a lack of discipline this method can often lead to a more expensive test program. Not because it has to, but because people get use to testing every single requirement, and often times you end up doing both. This method also runs into trouble if you start to believe the model being validated too early. Often a test program will run one or two tests which correlate very well with the model and jump to the conclusion that the model is correct without really exercising it. However, with the right mix of experienced test personnel and discipline this test approach yields a far more powerful result (a working model) than the traditional approach (volumes of data).

HIRDLS TESTING APPROACH

The testing approach recommended for the HIRDLS program is a hybrid of the two approaches described above. Because the nature of the program requires correlating data which will be taken over a five year period of time to an absolute standard, the test program must define absolute performance at instrument delivery and also provide the tools necessary to track and predict instrument performance over its five year life. The approach will therefore be to verify the function requirements of the instrument, validate the performance models for the instrument, and to perform extensive testing and calibrations at specific points within the operational and environmental envelopes. In our judgement, this combination yields the most accurate and versatile test product with the minimum amount of testing. This approach also allows for

incremental testing at various facilities should that yield programmatic cost advantages. Under this approach the HIRDLS instrument will not need to be tested or calibrated under every operational scenario or every environmental condition. And, it will certainly not be tested or calibrated under every possible operational and environmental combination.

Figure 1 shows the HIRDLS Radiometric Test Flow required to support and validate the various math models. It depicts the overall test and verification strategy as well as identifying how the verification of the individual requirements support the model data bases and validation. The following paragraphs describe in detail this approach.

MODELING

As part of developing the overall test approach it is important to understand what modeling is being done, how those models will be used, how they interact with each other, what are the critical elements of each model are, and how the models are characterized. This document will concern itself with only the models which directly affect the radiometric performance of the HIRDLS instrument. These models are: the Instrument Radiometric model, the Nearfield model (which may be integral to the Instrument Radiometric model and thus not be a stand alone model), the Optical model, the Thermal model, and the Structural model. The following subparagraphs describe what each of these models do (from a radiometric perspective), how they interact with each other, what their critical elements are and how they are typically characterized.

HIRDLS Instrument Radiometric Model

The Instrument Radiometric Model is the top level instrument performance model. Its function is to convert the data stream from each detector into absolute irradiance at the entrance aperture. It contains within it all the instrument calibration and gain tables and it takes inputs directly from the Nearfield model, and the optical model.

Nearfield Model

The function of the Nearfield Model is to predict the signal contribution, on a band-to-band basis, which is internally generated by the instrument (as a function of temperature). It takes active inputs from the Thermal Model (the instrument thermal map), and scan mirror position sensors (the scan mirror position sensors are required because the scan mirror emittance changes as a function of angle). It has data base inputs which include the emittances of all optical elements, the baffles, chopper, and sun shade and the quantum efficiency (radiometric spectral response) of each detector as a function of wavelength. The Nearfield Model also requires contamination estimates for each optical element. Because of the difficulty of measuring emittance and contamination on as built hardware, an instrument level test will need to be performed to validate the Nearfield Model. This test will need to be performed in a vacuum chamber while looking at a cold wall and varying the instrument temperature and scan mirror position. The purpose of this test is to develop the baseline instrument response over its temperature range and to provide detector response vs. element temperature at several points to validate the Nearfield model. In order to best validate the model, a method of varying the temperature of key elements (like the baffles and sunshade) independently may need to be developed. The validation of the Nearfield Model can be performed as part of the Thermal Model validation by including the above additions.

Thermal Model

The Thermal Model takes inputs from the temperature sensors and provides a complete thermal mapping of the instrument. This thermal map becomes the basis of the emittance calculations in the Nearfield Model. The Thermal Model also provides input into the structural model which in turn provides element movement to the Optical Model. The principal issues affecting the thermal model revolve around ensuring sufficiently accurate calibration of the temperature sensors and ensuring the sensors are placed where they will be most perceptive. The instrument will undergo Thermal Vacuum /Thermal Balance testing to ensure proper performance. During this set of testing, the Thermal Model can be validated. To aid in this validation, additional thermal sensors will be placed on the instrument to provide additional data for the thermal model to validate the instrument thermal response in areas not covered by flight monitors.

Optical Model

The Optical Model takes input from the Thermal and Structural Models and predicts the variations of the optical properties as a function of element distortion (from thermal gradients across an element) and element motion. The optical changes become inputs to the Radiometric model in the area of instrument vertical response. Validation of this model will come primarily by comparing the results obtained by analytically combining the test results of individual optical components with the instrument level optical test results. The most important aspect of this model is to insure it is updated with the as built prescription for each element. And that the element spacing is verified, which is done by an end-to-end distortion mapping at the TSS level.

Structural Model

The Structural Model takes the thermal map of the instrument, as a function of time, and predicts the resultant motion of optical elements. The motion of the optical elements become inputs to the Optical Model for calculating changes in optical distortions. Validation of this model will also require a Modal test to determine any resonance modes and may also require element sensitivity testing where individual elements have a small force applied to them and the resultant image motion monitored (this test would certainly be a TSS level test).

Individual Requirements Verification

In conjunction with the development of the model verification plan one must understand how individual requirements should be verified and how validation of these requirements affect the models. The following Sub-paragraphs describe on a requirement by requirement basis how each individual requirement could be verified. Also included within each sub-paragraph is a reference to which Math Model data base is impacted by that specific requirement.

3.3.1 Vertical FOV

Verification of this requirement will be a combination of test and analysis at the sub-system level. At the DSS level the physical dimensions will be verified. These dimensions become inputs to the Radiometric Model. At the TSS level the focal length will be verified and a distortion map of the instrument will be generated. These become data base inputs to the Optical Model. And, at the TSS/DSS integration level the instrument focus will be verified and input to the Optical Model as well. This focus test becomes the first instrument level verification of the Optical Model.

3.3.2 Vertical Response

Characterization of the Vertical Response Function will result in a mapping of the spatial energy distribution for the TSS/DSS combination in the Y (vertical) axis. This mapping, when combined with the 5x spatial over sampling of the atmosphere, will allow sub-detector spatial resolution to be achieved within a single scan. This test will need to be performed on axis to develop the Vertical Response Data Base for the Radiometric Model and at a few points (edge centers, and four corners) within the Scan Mirror field of regard to verify the Optical Modeling. The Optical Model will take the on axis Vertical Response data and combine it with the distortion map and Scan Mirror postition to predict the change in vertical response function over the field of regard. This will validate the distortion matrix within the Optical Model. This test is at instrument level and is baselined to be performed at vacuum; however, as instrument requirements and designs mature, it may become possible to satisfy these requirements at ambient. The results of this test become a key reconstruction Data Base within the Radiometric model. A generic approach to verification of this requirement is described below:

Step 1: Characterize the hot (300K) line source (wire or edge) through an auto-collimation approach. A mirror is placed in front of the collimator to retro-reflect it back through the collimator. The resultant double pass image is interogated by a quad-cell type detector by scanning this detector through the image and deconvolving the spacial energy distribution function. Because this is a auto-collimation test it will ensure the collimator is in focus if the return image falls at the same focal position as the source.

Step 2: Scan all 21 channels with the characterized line source. This may be done one column at a time, or with a full field width line source.

Step 3: By analysis, determine the vertical response function (detector response vs. angle (or position)) of each channel.

3.3.3 Vertical Response Stability

Long term stability requirements can only be satisfied by analysis, as will this one. However, to properly bound the analysis to instrument reality it becomes necessary to understand the factors which will determine the instruments stability. Within a single channel focal length stability, optical figure stability (especially following a gravitational release after launch), thermal stability, structural stability, and detector response stability are the primary factors which combine to determine overall channel stability. Between channels, tilt of individual filters with respect to each other is an additional factor. Ultimately, these requirements will be satisfied by a combination of the test and validation process for the thermal, structural, and optical models and DSS stability test data. The logic is as follows: if by properly modeling (and verifying) the thermal, structural, and optical inter-relationships of the instrument the optical stability under all environmental conditions can be predicted. By adding to this the DSS thermal stability test data and gain stability test data, the instrument Vertical Response Stability can be predicted over the life of the instrument. Note: in the detector and filter areas the effects of radiation over time may also need to be factored in. By comparing the pre-environmental Vertical Response data with post-environmental Vertical Response data a final stability can be made. This data will not directly impact any model unless specific time or temperature dependencies arise.

3.3.4 Horizontal Field of View

This requirement is verified in the same manner as the Vertical Response requirement was, except in the other axis. It is necessary to understand horizontal response to allow proper correlation of data in adjacent scans. Verification of this requirement will only need to be performed on axis; it will not need to be performed at various positions of the Scan Mirror field of regard as the Vertical Response Function was. This is because of the following: first, the field size in this axis is 72 times larger than in the vertical axis. Second, the horizontal pointing requirement is 35 time greater then that of the vertical axis. These facts combined to suggest this requirement is at least a order of magnitued less sensitive to optical distortions. Third, the response changes in this axis will primarily be due to field rotation, which is a smooth function of the cosine of the Scan Mirror angles.   Fourth, the distortion matirx within the Optical Model was verified in section 3.3.2 to a greater accuracy then would be required to meet this requirement. These facts all combine to suggest that Horizontal Field of View verification be performed on axis only and the Optical model be used to characterize the response over the field of regard.

3.3.5 Out of Field Response

Verification of this requirement will produce data base inputs to the Radiometric Model. The Out-of-Field response will vary as a function of scene irradiance not temperature so it is part of the Radiometric Model not the Nearfield Model. This will need to be an instrument level test and can be performed at one temperature only. Variations due to temperature will be accounted for by the Nearfield Model and the

Optical Models. This test is baselined to be performed in air but could also be combined with other vacuum tests. The following is one possible method of verification for this requirement.

Step 1: The image of a full FOV hot source is presented to the instrument using a long focal length (approximately 10 meter) collimator . A horizontal ambient temperature occulting stripe equivalent to ±4km x ±81.5Km is placed immediately in front of the extended hot target to produce an "inverted hot wire" type of target. The heated target is of sufficient extent to illuminate an area in excess of the full composite field of all 21 detector channels and the size of all instrument (oversized) field stops. The ambient stripe is imaged onto each row of detectors or onto each detector individually in turn while channel responses are observed for various temperatures of the background. Quantitative measuments are facilitated by an ambient temperature occulting panel used as a "chopper"to modulate the radiance from the heated background source.   The general arrangement of this test is shown in Figure 2.

Step 2: Analysis of the detector response data vs. background irradiance will privide the required data base for the Out-of-Field response correction in the Radiometric Model.

Figure 2, General arrangement for out of field testing

Wide Angle Stray Light

An additional aspect of characterizing the Out-of-Field response is investigation of the the instruments ability to surpress stray light from angles outside the composite field.   The angular effect will be characterized as a data base input to the Radiometric Model and so will the Stray Light transfer function (irradiance around aperture to detector output) This test will not include heating effects of the baffels or other elements. Those contributions will be corrected for with the Nearfield Model. This verification

could be performed in conjunction with the Nearfield Model verification by adding a moveable source in the chamber. With the instrument viewing a low radiance light trap,the radiation source is moved with relaative to the LOS.

3.3.6 Focusing Range

Verification of this requirement will be inspection (no focus adjustment designed in). However, the important issue here is to ensure the instrument is focused. This will be verified initially at the integrated DSS/TSS level.

3.4 Radiometric Specifications

Full characterization of each channels radiometric response, to the lspecification requirements must be done in several steps. First, relative spectral response (RSR) of each channel, defined in section 3.4.1, must be fully characterized on axis. This RSR characterization must then be repeated at several points in the scan mirrors field of regard to validate the equations within the Radiometric Model which predict these spectral shifts vs. mirror angle. Then, each RSR curve must be placed on an absolute radiometric response scale by calibrating the instrument against a full aperture traceable source (section 3.4.4). Finally, the absolute instrument gain, offset, and linearity must be calibrated. Verification of the requirements of this section must be done at the instrument level.

The most critical of these tests are the absolute requirements of section 3.4.4. Any errors, be they systematic or random, which affect these characterizations will directly effect the accuracy and precision of the Radiometric and Nearfield models, which together determine the absolute radiometric capabilities of the instrument. The spectral response requirements of sections 3.4.1 through 3.4.3 are also critical but they do not carry the same direct correlation to instrument absolute error. Small errors in the RSR curves will have a second order effect on the absolute instrument response.

3.4.1 Channel Spectral Response

The initial verification that the instrument spectral response conforms to the requirements stated in Table 3.4.1.-1 will be done by the Radiometric Model. The approach will be to analytically combine test data from individual optical elements (mirrors and filters) with the detector quantum efficiency curves to determine the spectral response of each channel. This is a straightforward task requiring only component and sub-system test data and will be sufficient for early verification of this requirement (in addition to component testing the TSS will be spectrally characterized at the TSS level). By exercising the Radiometric Model over the scan range of the mirror and the Nearfield Model over the thermal variations of the instrument the Channel Spectral Response can be predicted over the entire operational envelope.

The final verification and data base generation for the Radiometric and Nearfield models will occur in two steps. First, the instrument RSR for each channel will be determined on axis. This test must be performed at vacuum to mitigate the thermal effects, water absorption, and CO_2 effects of the atmosphere. A scanning, chopped monochromator will sweep the entire spectra from 4 µm to 20 µm at 0.3 µm intervals while each channels output is monitored. The data generated in this set of tests will be used to update the spectral response data sets in the Radiometric and Nearfield Models and will satisfy the verification requirements of this section and section 3.4.3.

3.4.2 Spectral Response Stability

The spectral response stability is another requirement which by its very nature (the requirement extends to end of life) must be satisfied by analysis. This requirement has three implied contributors to stability: mechanical, thermal, time. The mechanical stability of the instrument will be characterized during the structural model verification; the thermal stability will be characterized during the Thermal Model verification, and the stability over life will be addressed in the radiation analysis. The complete validation of these models however, will require some verification test data from component and sub-system level tests:

Thermal Stability:

In addition to the instrument level thermal and Nearfield testing described earlier, there is a need for specific DSS sub-system spectral response testing. At issue here is the potential spectral response variation of the DSS as a function of focal plane temperature. Also at issue is the possible response variations as a function of time since turn-on or time between modes (Mode Transition Time), which again is really a thermal stability issue (this MTT data may be required to facilitate data gathering within real operational timelines). Since the ability to conveniently exercise the DSS at various temperatures is limited at the instrument level, and since the detector variations are likely to be the major contributor to response variation it is necessary to fully characterize the detectors responsivity over time and temperature. The procedure will require taking RSR data at the DSS sub-system level for each channel at several detector operating temperatures between 60K and 80K (perhaps between 55K and 85K to bound the operating temperatures). The Mode Transition Time (MTT) test will require taking turn-on transient data to map the detector response from turn-on through thermal stability and between mode transitions. This data will be iused in both the Radiometric and Nearfield Models to correct the data for spectral shifts due to temperature.

Other components which have thermal dependencies which will affect the Spectral Response Stability are the optical system (primarily the spectral filters), the detector/electronic gain circuitry, and the In Flight Calibrator. The optical system thermal stability will be verified with the Thermal Model but filter spectral shifts as a function of temperature will need to be characterized at the filter level for inclusion into the Radiometric and Nearfield Models. The Electronic gain circuitry will require special subsystem level verification over its operating range. This can be accomplished at the system level thermal vacuum testing. And the IFC will require extensive thermal testing and verification at the Sub-system level.

Mechanical

The only place the mechanical stability comes into the radiometric model is through its contribution to motion in the optical system. This contribution will be fully characterized through the verification process of the Structural and Thermal Models. The only component specific mechanical issues are with the vibration which could be introduced to the optical system by the cooler and the chopper. These issues however, are more vibration/pointing related than specifically radiometric. But, the effects of these components will be fully characterized at the subsystem level and their test results input into the structural model.

Life

Life as addressed here implies two main issues: contamination and radiation degradation. The contamination baseline will be determined during the Nearfield Model verification tests and will be updated occasionally during life based upon inflight calibration data. The radiation issue will be satisfied by parts selection and component testing as required.

3.4.3 Out-of-Band Response

As stated earlier the Out-of-Band response will be determined by the data taken in 3.4.1 and will be part of the optical system radiometric response data base within the Radiometric Model.

3.4.4 Radiometric Performance

The difficulty in performing any "absolute" measurements, let alone measurements to better then 1%, is the construction and validation of the test source and facility. Every time the source/facility environment is changed, which includes opening doors, installing instruments, and cleaning the floors, the traceability of the source and facility back to absolute truth must be questioned. For this reason, it is recommended that the characterization of the instruments absolute accuracy occur at the end of the test program and only be performed once. Traditionally, a characterization such as this would be performed several times in the test program (to verify stability) and at all positions within the field of regard (to characterize field dependence). In this case however, multiple characterizations to better then 1% absolute accuracy are simply impractical. So, in order to minimize the risk of leaving one of the most critical verifications to the end, the test program will be developed to ensure the final characterization will only be a conformation and calibration of previously tested requirements. This will be accomplished through piece wise verifications with the various models and tests designed to ensure the instrument is calibratable to the required levels. Then, once the instruments calibratability and stability is determined, it will undergo an absolute calibration of each detector channels gain, offset, and linearity. This characterization will be performed at the instrument level and will need to be performed in a vacuum chamber to minimize the thermal, water, and CO_2 contributions and of the atmosphere. Any errors in these calibrations will directly effect the accuracy and precision of the instrument and the Radiometric and Nearfield models, which together determine the absolute radiometric capabilities of the HIRDLS experiment. All measurements at this level of testing will need to be performed with a full aperture source which has been calibrated in its test facility to better than 1% absolute radiometric error.

Currently Lockheed has no ability (black body or facility) which is certifiable to produce absolute radiometric calibration to the 1% specification requirement. Facilities could be modified and characterized and a black body could be fabricated or procured and characterized to meet the specification verification requirements but currently this capability does not exist. Lockheed does have a black body source which is certifiable to 3% absolutely but would not be adequate for full aperture testing. This black body source could be used with a collimator (thus reducing its absolute accuracy but not affecting its stability) to provide a sufficiently stable source to ensure the HIRDLS instrument can be calibrated and to determine the instruments response variation as a function of scan mirror angle.

3.4.4.1 Radiometric Accuracy

Verification of the instrument radiometric accuracy will be done in three steps. The first step is to verify the Optical and Radiometric Models by performing a radiometric calibratability baseline test. This will utilize a BB source (presumably the 3% source with collimator) in a vacuum chamber to fully characterize the "relative" radiometric response of all 21 channels of the instrument. The word "relative" is used here because this baseline test is not intended to provide absolute radiometric accuracy's. Its purpose is to first, provide an instrument level baseline radiometric calibration, second, to validate the Radiometric Model, third, to update the Nearfield Model, and finally to dry-run the radiometric calibration procedure.

The second phase of testing will repeat the first phase at the extreme edges of the scan mirror field of regard. The data taken will be used to verify the equations within the Radiometric and Nearfield Models which predict the radiometric response changes as a function of mirror position. What is important in this test is to use the exact same test arrangement and equipment used in phase one to ensure the proper radiometric mapping. The one equipment addition is a way to rotate the instrument without disturbing the test set-up.

The third phase of radiometric accuracy testing is to perform the absolute radiometric calibration. Since phase two testing above characterized the radiometric shifts vs. scan mirror angle, and the DSS radiometric response has been fully characterized over temperature, and the Nearfield Model has been validated over temperature the instrument absolute radiometric calibration can be confined to the on axis position only at one temperature. As stated earlier, this test will require a full aperture source in a vacuum chamber which is absolutely calibrated to better then 1% total radiometric error. The purpose of this test is to position the relative response curves generated in 3.4.1 onto an absolute scale.

3.4.4.2 Radiometric Channel Gain

The gain calibration for each channel is very straightforward in theory. The instrument is thermally stable and on the optical axis. The temperature is swept between $100 < T < 300K$ in approximately 10K increments. Each detector is sampled for at least 10 seconds to ensure the proper statistical sample has been taken for each detector (note: scan mirror position may need to be moved for each detector). Won't the data has been taken the source is move to the next temp, stabilized, and the next data level is taken. This test must be taken with the absolute test source in the chamber.

3.4.4.2.1 Radiometric Channel Gain Stability

This can be performed without the need of an absolutely calibrated source. What is required for this test is to ensure that the source used is radiometrically and thermally stable for long periods of time. The gain stability has two parts to it: within a detector cool down cycle and between cool down cycles. Both must meet the requirement of this section. The testing will cover both issues. The first, within a cool down cycle can be done be arranging the gain calibration test in such a way as to repeat several temperatures during the test. The latter must be done several times (e.g.. before and after environmental tests etc.) A minimum of 10 seconds of data will need to be taken to ensure the proper statistical sample.

3.4.4.3 Radiometric Channel Offset

The electronic offset of each channels telemetry will have been set during engineering tests to the required 1000 +/-250 counts. The verification of this requirement will be combined with the gain calibration of section 3.4.4.2. Final verification is to ensure the telemetry output at a temperature < 100K meets the requirement.

Note: The channel offset will most likely set at the DSS level. This is a detail which will be determined as the design matures. If the gain setting occurs at the instrument level, because of a higher level addition of the digitization electronics the offset could be set by the following procedure:

Step 1:   In the cold vacuum chamber, the instrument response is verified in each channel to demonstrate by test that the analog offset of each radiometric channel is set such that the

telemetry data output value is 1000 ±250 when the instrument is viewing a blackbody at a temperature = 100K.

Step 2:   Ten-second averaging testing will be conducted to achieve the required measurement precision through the telemetry channel.

Step 3:   Radiometric offset stability will be determined from the test results using a (TBD) algorithm.

3.4.4.4 Radiometric End-to-end Linearity

Verification of the instrument linearity will require the use of the absolutely calibrated full aperture source. The large signal linearity will be satisfied by the data taken during the radiometric gain calibration of section 3.4.4.2. However, this large scale gain factor may mask the small scale localized gain factor which would affect the instrument accuracy. For that reason a small signal gain factor should be determined at various positions within the dynamic range. This can be accomplished by overlaying a small signal source with a large signal source through a collimator. This test does not necessarily require an absolutely calibrated source. What it requires is that the irradiance of each source be well characterized relative to each other. This test would only need to be performed on axis.

3.4.4.5 Crosstalk

The results of verifying this requirement will only validate system functionality; it will not provide specific data to any model. Testing this function will be a Pass/Fail test to ensure channel electronic crosstalk does not contaminate the scientific data.

Step 1:   Electrical Crosstalk - Inject signals at the donor channel pre-amp inputs of the IPS. Measure the resultant change in receptor channels.

Step 2:   Use analytical routine to calculate crosstalk error.

3.4.5 Radiometric Noise

Verification of this requirement is the direct result of the validation of the Nearfield Model as described above.

3.4.6 Dynamic Range

This requirement can be verified through the combination of the Nearfield Model verification testing and the gain calibration of section 3.4.4.2. This data will only validate system functionality it will not provide specific data to any model.

3.4.7 Radiometric Digitization

Satisifaction of this requirement will come from analysis of the data from sections 3.4.1 and 3.4.4

3.4.8 Radiometric Signal Processing

3.4.9 In-Flight Radiometric Calibration

The verification/calibration of the In-Flight calibrator consists of repeating the radiometric gain calibration of section 3.4.4.2 in an alternating manner between the absolute source and the IFC. The absolute source and the IFC will be set to the same temperatures, the Scan Mirror will move to view the absolute source and data will be taken. Then the mirror will move to view the IFC and data will be taken. The source temperatures will then be changed and the process repeated. The difference in data taken from the IFC with respect to the absolute source will constitute the IFC Cal. Curve. Note: This procedure will remove the errors associated with the Scan Mirror refelctivity vs. angle variation between the primary path and calibrator path.

RECOMMENDATIONS

The development of a test document of this nature, at this point in the program almost by definition makes the entire document a recommendation; there are few test issues which are truly cast. In taking this recommendation one step further, it makes sense to analyze the above information to see how the available facilities could be best fit around the requirements. In looking at the logic of instrument integration and how intimately the requirements verification and model verification are intertwined, it becomes apparent that a vacuum chamber test facility is required at the integration facility which is capable of accepting the integrated instrument and test sources. It also is probable that this test facility will require some method for elevating the instrument temperature at various times in the integration. For this reason it appears that the SEARCH chamber in Building 205 of Lockheed's Palo Alto facility is the chamber of choice. This facility will require some clean-up prior to instrument arrival and will require out-fitting with a Laminar flow clean tent to protect the instrument while the chamber door is open. From a cost perspective, upgrading this facility will be far less expensive and provide a more spacious facility than an upgrade to the Red chamber. The STF chamber offers no real advantage over the SEARCH chamber for the HIRDLS program. It has several negatives like it is further from the integration facility and is considerably more expensive to operate. Its only apparent advantage is that it is already equipped with a LHe cold wall. However, HIRDLS does not need LHe temperatures for testing.

The one negative of all these facilities is that none are currently capable of supporting the 1% absolute radiometric calibration requirement of the HIRDLS program and there are no plans to upgrade them to do so. However, the program is afforded two advantages on this issue: first, the difficult nature of achieving the 1% absolute radiometric calibration suggests a natural separation between these verifications and all other verifications. And second, a facility is currently being upgraded at Oxford to provide the required calibration capability. Therefore it is recommended that the Absolute Radiometric Calibrations required in sections 3.4.4.1, 3.4.4.2, 3.4.4.2.1 as a verification only, and 3.4.4.3 be performed at the radiometric facility in Oxford. In addition, some additional (TBD) subset of tests would need to also be performed at Oxford to ensure proper instrument performance traceability between facilities. It is also recommended that all other tests be performed at the Lockheed Palo Alto facilities except the instrument environmental tests, which would be performed at the Lockheed facilities in Sunnyvale, California.

Appendix A
LOCKHEED'S RADIOMETRIC TEST FACILITY DESCRIPTION

Radiometric testing requires operation in vacuum, while LOS testing, for the most part, can be conducted in air, with proper set up to minimize disturbance from atmospheric turbulence. Vacuum is essential to create a proper environment for the instrument so that it can reach proper thermal equilibrium, the chopper will operate without aerodynamic drag and disturbance, and atmospheric absorption is eliminated between the radiometric sources and the detector array. Three vacuum test chamber facilities have been identified at Lockheed as candidates for radiometric testing of the HIRDLS instrument. These are two chambers at the Palo Alto Research Laboratory, and one at the Lockheed Sunnyvale facility. Other, generally larger, chambers exist at Lockheed, including those which will be used for environmental test, but these have not been considered as serious radiometric facility candidates, primarily for cost reasons. The three candidate chamber facilities are discussed below.

RED CHAMBER

LOCATION:

The Red Chamber facility is located in LPARL's LWIR laboratory in building 202, room 2D29, approximately 50 meters from the HIRDLS cleanroom instrument assembly area, and 100 meters from the HIRDLS program office area. The facility layout is shown in Figure A-01, with the HIRDLS instrument is shown in a payload antechamber in test position.

PERSONNEL ACCESS:

The Red Chamber facility is a controlled access area for high value space payloads. An access list of individuals is used to allow entry only by authorized personnel.

SIZE:

The Red Chamber cylinder is 2.5 meters long with an outside diameter of 1.73 meters. With its nitrogen shroud in place, a volume the full length of the chamber with a clear inside diameter of 1.32 meters is available for housing optics and target sources.

STATUS:

The Red Chamber facility is presently configured for use as a 20K high vacuum environment for both simulation sources/optics and the payload under test, usually a small instrument or focal plane detector array.

Figure A-01   Red Chamber Facility Layout for HIRDLS

VIBRATION ENVIRONMENT:

The Red Chamber cryovacuum support equipment has recently been surveyed for vibration sources, and has been fitted with vibration isolation devices. As listed in Figure A-02, the measured power spectral density peaks translate into displacements at the Red chamber test pallet. In A-02, **M** is the velocity line spectrum with units of inches squared per second squared (per line). A line bandwidth of 1 Hz was used in the calculations because of the line source characteristic of the facility equipment. The frequency dependent damping **d** is a feature of the instrument passive isolation. As a conservative method of assigning angular displacement to each value of linear displacement, the factor 0.103 microradian per microinch, derived from the BDD figure 4.1.5-1 Baseline Focal Plane Layout was used, implying a 257mm lever arm for the displacements. This assumes worst case angular errors as large as if the focal plane traversed the full displacement in an otherwise stationary instrument.

frequency	damping factor	velocity line	velocity	displacement	damped disp.	angular disp.
f	d	M	V	x (at inst. base)	x' (at OBA)	a
(Hertz)	dimensionless	$[(\text{in/sec})^2]$	(in/sec)	(µinches)	(µinches)	(µradians)
measured	$(20Hz/l)^2$	measured	SQRT(delta f*M)	V/(2*pi*f)	x*d	x'*0.103
18	1.23	2.00E-08	1.41E-04	1.25	1.54	0.159
27	0.549	9.00E-08	3.00E-04	1.77	0.970	0.0999
29	0.476	2.50E-08	1.58E-04	0.868	0.413	0.0425
45	0.198	3.00E-08	1.73E-04	0.613	0.121	0.0125
58	0.119	4.00E-08	2.00E-04	0.549	0.0653	6.72E-03
60	0.111	1.50E-07	3.87E-04	1.03	0.114	0.0118
95	0.0443	2.00E-08	1.41E-04	0.237	0.0105	1.08E-03
			RSS Totals	2.55	1.83	0.189
			RSS without 18 Hz	2.30	1.06	0.109

Figure A-02   Red Chamber PSD Analysis

The primary source of vibration is the helium compressor, followed by the helium expansion engine, both of which would not be operating for HIRDLS radiometric testing. With the helium system running, displacements of 46 nanometers were measured on the chamber test pallet. Under a worst case analysis for HIRDLS, this displacement would translate to an angular displacement of 0.19 microradians.

CLEANROOM :

The Red Chamber facility is co-located with a 2.75 meter by 7 meter top-to-bottom laminar flow scrubdown room. This area is used for preparing payloads for insertion into the test position in the chamber. The flow originates at the HEPA filters in the ceiling, and returns at the base of the 2.75 meter long wall furthest from the red chamber.

RADIOMETRIC BACKGROUND VS HIRDLS REQUIREMENTS:

The Red Chamber radiometric background with the nitrogen shroud alone is suitable for radiometric characterization of the HIRDLS instrument.

HIRDLS INSTRUMENT TESTING:

The Red Chamber facility is barely large enough to accommodate HIRDLS testing. A payload antechamber large enough to accommodate the instrument and its 25° tilted rotary platform to scan over a +20 to -42 degree azimuth range will fit in the test prep area. The antechamber will not however comfortably pass through all of the doorways between the assembly cleanroom and the chamber room. The instrument would instead be double bagged for transport between the two rooms without the antechamber.

ADVANTAGES:

The Red Chamber facility is the most conveniently located Lockheed facility to the assembly cleanroom. Its size, vibration environment and radiometric background are suitable for HIRDLS radiometric testing. It can be configured to accommodate the instrument azimuth range inside its antechamber. It is under facility custody and operated by the same people responsible for integration and assembly of the HIRDLS instrument, eliminating the need for handoff of custody. The facility is secure from unauthorized access to the HIRDLS flight hardware.

DISADVANTAGES:

The Red Chamber facility is of marginal size for HIRDLS testing. The payload antechamber will need to be constructed of two bolt-together truncated cylindrical sections in order to fit through the doors. When assembled, it is captive within the facility because of its size; it cannot be used as a clean vessel for transporting the instrument to and from the cleanroom. The instrument instead will have to be double bagged for transfer between rooms, but without its shipping container, as it would require for transport to another facility. The antechamber will need to be moved out of the way to admit the instrument into the test area, then moved back for instrument loading into the test position. One chamber door requires modification to incorporate a vacuum isolation gate valve between chambers. The proposed antechamber, its rear door and the isolation valve (if used) are not yet specified or procured.

SENSOR TEST FACILITY

LOCATION:

The STF is located in LMSC's Sunnyvale, CA plant in building 150 at column H11.

ACCESS:

Presently, classified data processing is being conducted at the STF computer system. Controlled entrance with escort requirements or a Secret clearance are required. Accommodations can be made for separating instrument test facilities from the data processing work.

SIZE:

The STF Chamber is a 4.26 meter long, 2.43 meter diameter pressure vessel (Figure A-03). A removable 20K helium cooled metering structure containing IR sources and collimating/scanning optics resides in the chamber, enveloped by a 20K helium cooled shroud. The helium shroud is in turn enveloped by a nitrogen cooled shroud. A 0.84 meter diameter vacuum isolation valve separates the chamber from a payload antechamber (Figure A-04). To date, STF payloads have required antechambers less than 1.2 meters in diameter.

Figure A-03 STF Chamber on Pneumatically Isolated Pad

Figure A-04 STF Chamber with Isolation Gate Valve, and Payload Antechamber in Cleanroom

STATUS:

The STF facility has been determined to be surplus to the facility requirements of the Lockheed division which owns it. It is for sale in whole or in part, and is scheduled to be auctioned during 1995.

VIBRATION ENVIRONMENT:

The STF was characterized in 1982 after vibration isolation devices were implemented on the main chamber/antechamber pad, and on the helium compressor. The primary source of vibration was the helium compressor, which was replaced six years ago with a smaller unit. Helium cooling equipment would not be operating for HIRDLS radiometric testing. With the old helium system running, displacements of 178 nanometers were measured on the chamber. Under a worst case analysis for HIRDLS, this displacement would translate to an angular displacement of 0.7 microradians.

frequency	damping factor	acceleration line	acceleration	displacement	damped disp.	angular disp.
f	d	G	a	X (at inst. base)	x' (at OBA)	a
(Hertz)	dimensionless	gSQR/Hz	in/sec^2	(µinches)	(µinches)	(µradians)
measured	$(20\ Hz/f)^2$	measured	SQRT(delta f*G)	$a/(4*(pi*f)^2$	x=d	x'=0.103
9	1.00	3.00E-09	0.0211	6.61	6.61	0.681
22	0.826	8.00E-09	0.0345	1.81	1.49	0.154
30	0.444	1.50E-08	0.0473	1.33	0.591	0.0609
33	0.367	6.00E-08	0.0946	2.20	0.808	0.0832
36	0.309	2.00E-08	0.0546	1.07	0.329	0.0339
40	0.250	4.00E-08	0.0772	1.22	0.306	0.0315
44	0.207	1.00E-07	0.122	1.60	0.330	0.0340
			RSS Totals:	7.55	6.85	0.705
			RSS without 9Hz:	3.20	1.70	0.175

Figure A-05 STF Chamber PSD Analysis

CLEANROOM :

The STF cleanroom is a 7.3 by 12 meter class 1000 horizontal laminar flow room, with the capability for class 100 work in one corner up near the HEPA filter wall. An air shower in an interlocked booth permits access from the change room to the test area.

RADIOMETRIC BACKGROUND VS HIRDLS REQUIREMENTS:

The STF Chamber radiometric background with the nitrogen shroud alone is suitable for radiometric characterization of the HIRDLS instrument.

HIRDLS INSTRUMENT TESTING:

The STF is well sized to accommodate HIRDLS testing. A payload antechamber large enough to accommodate the instrument and its 25° tilted rotary platform to scan over a +20 to -42 degree azimuth range will readily fit in the cleanroom test prep area through 3 meter high double doors on the wall furthest from the chamber. The instrument would be double bagged in the instrument shipping container for transport from the building 202 cleanroom assembly area in Palo Alto.

ADVANTAGES:

The Sensor Test Facility size, vibration environment, radiometric background and cleanroom make it a suitable facility for HIRDLS instrument level radiometric characterization. It is already configured to accommodate HIRDLS flight hardware if an appropriately sized antechamber is made. The facility is secure from unauthorized access to the HIRDLS flight hardware.

DISADVANTAGES:

The STF is presently inactive and has been declared surplus. Funding is required to resurrect it from over a year of mothballing. The vacuum seals are suspect after so long a period, but may be fine. In addition, the HIRDLS program would incur large depreciation and maintenance costs during the period of preparation and use. Although ownership of the flight hardware would be maintained by the HIRDLS program, day-to-day custody would be entrusted to STF personnel.

SEARCH CHAMBER

LOCATION:

The SEARCH Chamber facility is located in building 205, near to Lockheed's LPARL receiving dock. It is in a different building from the HIRDLS cleanroom instrument assembly area, but the two areas are connected by a tunnel and elevator.

ACCESS:

The SEARCH Chamber facility is a controlled access area for high value space payloads. An access list of individuals is used to allow entry only by authorized personnel.

SIZE:

The SEARCH Chamber cylinder is 4.9 meters long with an outside diameter of 2.43 meters. With its liquid nitrogen shroud in place, a volume the full length of the chamber with a clear inside diameter of 2.13 meters is available for housing optics, target sources and the HIRDLS instrument.

STATUS:

The SEARCH Chamber facility is presently configured for use as an 80K high vacuum environment for both simulation sources/optics and the payload under test.

VIBRATION ENVIRONMENT:

The SEARCH Chamber has been used for precision pointing testing of optical systems, as well as radiometric testing of space infrared instrument payloads. With its pneumatically isolated table, the

facility has achieved backgrounds as low as 30 nanoradians. Without the isolation table (incompatible with HIRDLS testing due to its size), vibration survey results revealed power spectral densities similar to those measured in the STF chamber survey.

Figure A-06 SEARCH Chamber accommodates HIRDLS Instrument Full Azimuth Range
(chamber and instrument shown in proper relative scale)

CLEANROOM:

For use with a payload like the HIRDLS instrument, a complete facility cleanup is required, in addition to setup of a portable clean room at the mouth of the chamber. Suitable portable downflow cleanroom facilities are available for use with HIRDLS.

RADIOMETRIC BACKGROUND VS HIRDLS REQUIREMENTS:

The SEARCH Chamber radiometric background with the liquid nitrogen shroud alone is suitable for radiometric characterization of the HIRDLS instrument.

HIRDLS INSTRUMENT TESTING:

The SEARCH chamber is well sized to accommodate HIRDLS testing; a payload antechamber is not required. A 25° tilted rotary platform to scan over a +20 to -42 degree azimuth range will fit in the chamber along with the target sources and optics. The instrument would be double bagged in the instrument shipping container for transport from the building 202 cleanroom assembly. Transport can be accomplished trough the interconnecting tunnel or, via truck from the nearby B202 loading dock (near the instrument assembly clean room), to the SEARCH chamber.

ADVANTAGES:

The SEARCH chamber presents the lowest cost solution to HIRDLS radiometric testing at Lockheed. The facility is owned and operated by the same people in charge of integration and assembly of the HIRDLS instrument, eliminating the need for handoff of custody. The facility is secure from unauthorized access to the HIRDLS flight hardware.

DISADVANTAGES:

The SEARCH chamber is presently unable to provide the desired clean environment required for the HIRDLS instrument. Facility improvements to upgrade its cleanliness capability are required.